CEBAF Program Advisory Committee Nine
Extension and Update Cover Sheet

This update must be received by close of business on Thursday, December 1, 1994 at:

CEBAF
User Liaison Office, Mail Stop 12 B
12000 Jefferson Avenue
Newport News, VA 23606

Experiment: E -

Check Applicable Boxes:

☑ Extension ☐ Update ☐ Hall B Update

Contact Person

Name: PAUL STOLER
Institution: RENSSELAER POLYTECHNIC INSTITUTE
Address: PHYSICS DEPT.
Address: R. P. I.
City, State ZIP/Country: TROY NY 12180
Phone: (518) 276-8388 **FAX:** (518) 276-6680
E-Mail → Internet: STOLEP@RPI.EDU

CEBAF Use Only

Receipt Date: 12/15/94

By: P PR 94-138

BEAM REQUIREMENTS LIST

CEBAF Proposal No.: ______________________ Date: ______________
(For CEBAF User Liaison Office use only.)

List all combinations of anticipated targets and beam conditions required to execute the experiment. (This list will form the primary basis for the Radiation Safety Assesment Document (RSAD) calculations that must be performed for each experiment.)

Condition #	Beam Energy ~~(MeV)~~ GeV	Beam ~~Current~~ (μA) Luminosity $cm^{-2}s^{-1}$	Polarization and Other Special Requirements (e.g., time structure)	Target Material (use multiple rows for complex targets — e.g., w/windows)	Target Material Thickness (mg/cm^2)
	6	1×10^{34}	none	H_2 gas	High pressure H_2 gas

Beam energies, E_{Beam}, available are: $E_{Beam} = N \times E_{Linac}$ where N = 1, 2, 3, 4, or 5. For 1995, E_{Linac} = 800 MeV, i.e., available E_{Beam} are 800, 1600, 2400, 3200, and 4000 MeV. Starting in 1996, in an evolutionary way (and not necessarily in the order given) the following additional values of E_{Linac} will become available: E_{Linac} = 400, 500, 600, 700, 900, 1000, 1100, and 1200 MeV. The sequence and timing of the available resultant energies, E_{Beam}, will be determined by physics priorities and technical capabilities.

LAB RESOURCES REQUIREMENTS LIST

CEBAF Proposal No.: ______________________ Date: ______________
(For CEBAF User Liaison Office use only.)

List below significant resources — both equipment and human — that you are requesting from CEBAF in support of mounting and executing the proposed experiment. Examples would include new support structure; major installation projects; new cryogenic connections; new software; and major equipment such as power supplies or targets. Do not include items that will be routinely supplied to all running experiments, such as technical support for routine installation and maintenance.

Standard Hall B operating conditions
with pressurized gas H_2 target.
6 GeV Beam.

HAZARD IDENTIFICATION CHECKLIST

CEBAF Proposal No.: ______________________ Date: ______________
(For CEBAF User Liaison Office use only.)

Check all items for which there is an anticipated need.

Cryogenics _____ beamline magnets _____ analysis magnets _____ target type: _________ flow rate: _________ capacity: _________	**Electrical Equipment** _____ cryo/electrical devices _____ capacitor banks _____ high voltage _____ exposed equipment	**Radioactive/Hazardous Materials** List any radioactive or hazadorous/ toxic materials planned for use: _________________ _________________ _________________ _________________
Pressure Vessels _____ inside diameter _____ operating pressure _____ window material _____ window thickness Standard Hall B ~~pressurize~~ pressurized H_2 target	**Flammable Gas or Liquids** type: H_2 flow rate: _________ capacity: _________ standard Hall B **Drift Chambers** type: _________ flow rate: _________ capacity: _________ Standard Hall B	**Other Target Materials** ___ Beryllium (Be) ___ Lithium (Li) ___ Mercury (Hg) ___ Lead (Pb) ___ Tungsten (W) ___ Uranium (U) ___ Other (list below) _________________ _________________
Vacuum Vessels _____ inside diameter _____ operating pressure _____ window material _____ window thickness	**Radioactive Sources** _____ permanent installation _____ temporary use type: _________ strength: _________	**Large Mech. Structure/System** _____ lifting devices _____ motion controllers _____ scaffolding or _____ elevated platforms
Lasers type: _________ wattage: _________ class: _________ Installation: _____ permanent _____ temporary Use: _____ calibration _____ alignment	**Hazardous Materials** ____ cyanide plating materials ____ scintillation oil (from) ____ PCBs ____ methane ____ TMAE ____ TEA ____ photographic developers ____ other (list below) _________________ _________________	**General:** Experiment Class: ✓ Base Equipment _____ Temp. Mod. to Base Equip. _____ Permanent Mod. to Base Equipment _____ Major New Apparatus Other: _________ _________

EXCITED BARYONS AT HIGH MOMENTUM TRANSFER WITH THE CLAS

Extension of Experiment 91-002 to 6 GeV Electron Beam

The N* Collaboration +

P. Stoler: co-spokesperson, contact person

V. Burkert, Z. Li, M. Taiuti: co-spokespersons

Abstract

We propose to extend the kinematic range of experiment 91-002 from a maximum Q^2 of about 4 GeV^2/c^2 to about 7 GeV^2/c^2 by utilizing a beam energy of 6 GeV. We request 720 hrs (30 days) of unpolarized beam, at a luminosity of approximately 1×10^{34} $cm^{-2}s^{-1}$. We will measure the properties of excited nucleons by means of exclusive single meson production. The motivation is to investigate short range phenomena in baryon structure, and by obtaining the individual contributing helicity amplitudes we will obtain informaton about the transition from the low Q^2 non-perturbative regime, where theoretical descriptions have used constituent quark models, to higher Q^2 where it is believed perturbative QCD plays an increasingly important role. Among the specific transitions which we will study are the evolution of the $P_{33}(1232)$, $S_{11}(1535)$, and $F_{15}(1680)$ form factors.

. +The members of the Hall B CLAS N* collaboration are: G.Adams[3], M. Anghinolfi[8], K. Beard[10], N. Bianchi[7], G.P. Capitani[7], V.Burkert[1], R. Chasteler[6], C.Carlson[4], A. Coleman[4], D. Cords[1], P. Corsiviero[8], D. Crabb[2], D.Day[2], E. De Sanctis[7], S.Dytman[11], L.Dennis[9], D.Doughty[5], P. Dragovich[9], L. Elouadrhiri[5], H.Funsten[4], M.Gai[15], G. Gervino[8], K.Giovanetti[12], D. Heddle[5], P. Levi Sandri[7], Zh. Li [5], J. Lieb[14], M. Manley[13], R. Marshall[2], L. Mazzaschi[8], J. McCarthy[2], B.Mecking[1], M.Mestayer[1], R.Minehart[2], V. Mokeev[8], M. Muccifora[7], N.Mukhopadhyay[3], B.Niczyporuk[1], D. Pocanic[2], O.Rondon-Aramayo[2], J. Napolitano[3], E. Poli[7], G. Ricco[8], M. Ripani[8], A.R. Reolon[7], P. Rossi[7], M. Sanzone[8], R.Sealock[2], E.Smith[1], L.C. Smith[2], P.Stoler[3], M. Taiuti[8], D.R. Tilley[6], T. Tung[4], S.Thornton[2], H.Weber[2], H. Weller[6], B. Wojtsekhowski[1], A.Yegneswaran[1], A. Zucchiatti[8]

[1]CEBAF, [2]Univ. of Virginia, [3]RPI, [4]William & Mary, [5]Christopher Newport, [6]Duke, [7]INFN-Frascati, [8]INFN-Genova, [9]Florida State, [10]Hampton, [11]Univ. of Pittsburgh, [12]James Madison, [13]Kent State, [14]George Mason, [15]Univ. of Conn.

I. Physics Background

One of the fundamental subjects in physics is the non-perturbative structure of baryons and their excitations in terms of elementary quark and gluon constituents. A central issue concerns which models are valid for describing these excitations in different domains of Q^2. At low Q^2 (< 1 GeV^2/c^2), the structure is very complex and as yet unsolved, whereas the constituent quark model (CQM) has proven to be a very powerful and widely accepted basis. At moderate $Q^2 < 3$ GeV^2/c^2 recent relativistic extension of the CQM in the light cone formalism (As-94) gave very encouraging results for the nucleon form factors and some (poorly known) resonance transitions. At asymptotically high Q^2 the physics is expected to be greatly simplified since the interactions are describeable in terms of perturbative QCD (pQCD) and the structure involves only the minimum number of current quarks. The distribution functions of these valence quarks are determined by their non-perturbative interaction with the complicated QCD vacuum, and this gives us a handle on treating the non-perturbative QCD structure of a hadron.

There is currently a great deal of controversy about what domain of Q^2 corresponds to the transition from non-perturbative to perturbative descriptions. For inclusive deep inelastic scattering from individual quarks it is well known that pertubative descriptions begin to be valid at Q^2 as low as 1 or 2 GeV^2/c^2. However, for exclusive reactions involving the coherent behavior of several guarks the transition to perturbative descriptions is expected to take place at higher values of Q^2. There are a variety of exclusive data which (inconclusively) appear to approach the predicted pQCD dimensional counting rules at surprisingly low Q^2, ie. as low as a few GeV^2/c^2, which is well below the asymptotic Q^2 predicted by theory. At this time one may say that a satisfactory understanding of exclusive reactions in the multi-GeV regime eludes us. In order to make important progress in understanding the reaction mechanism we must look at fundamental systems for other experimental observables as well as Q^2 scaling.

There are two important aspects of exclusive reactions. On one hand there is the hierarchy of the Q^2 dependence of the transition amplitudes, which are related to the relative complexities of the participating states. In the pQCD limit only the Fock state consisting of valence quarks is supposed to contribute, leading to the well defined Q^2 counting rules. The saturation of these counting rules would be an indication of the approach to the domain where perturbative calculation techniques would be valid. However, the agreement of the predicted dimensional scaling is not conclusive evidence for the onset of pQCD, since calculations using constituent quark models, or even traditional non-quark models can, in specific cases mimic the pQCD predicted scaling behavior.

Fortunately there are other predictions of pQCD calculations which can be tested for the first time with CEBAF. For example the quark distribution function manifests itself in the magnitudes of the the exclusive cross sections, and helicity conservation imposes important restrictions on the relationships between contributing helicity amplitudes or multipoles.

The physics in the case of baryon resonance transitions has been reviewed in some detail in St-93. A short summary of the issues is presented here. The form factors may be expressed in terms of the allowed electromagnetic multipoles or helicity elements. At high Q^2 they can be factorized utilizing quark helicity conservation (Br-89):

$$F(Q^2) \ = \ \int_0^1 \int_0^1 dx dy \ \Phi_f(y)^* \ T_H \ \Phi_i(x),$$

where $x \ = \ (x_1, x_2, x_3)$ and $y \ = \ (y_1, y_2, y_3)$ denote the longitudinal momentum fractions of the valence quarks of the initial and final baryon state. The two main ingredients are the hard transition operator T_H, which is purely perturbative and the three-quark distribution amplitudes Φ, which reflect the non-perturbative interaction of the valence quarks with the QCD vacuum.

The transition operator T_H to leading order in pQCD is determined by diagrams such as in Figure 1, where three quarks absorb the virtual photon and remain intact by means of the exchange of two hard gluons. This leads to the functional form

$$T_H \;=\; \frac{\alpha_s^2(Q^2)}{Q^4} f(x, y, Q^2).$$

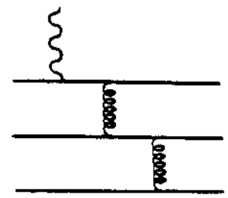


Figure 1. Example of a leading order diagram contributing to the perturbative hard scattering amplitude T_H.

The form factor is then predicted to scale as Q^{-4}, modulated by logarithmic decreases due to the Q^2 dependence of the running coupling constant α_s, and the evolution of the distribution amplitude.

The valence quark distribution amplitudes $\Phi(x)$ determine the form factor normalizations and signs. At moderate Q^2, say a few GeV^2/c^2, more complicated processes involving sea quarks and gluons interacting non-perturbatively play important roles. Exactly what is the role of more complicated soft processes vis-a-vis leading hard processes at moderate Q^2 is a very controversial issue. From the available data our assessment is that we just don't know. The the Q^2 dependence of the elastic proton form factor is one of the few pieces of baryon data available. However, there is a controvesy about whether Φ obtained from QCD sum rules can explain the observed magnitude. Exclusive data on the separated helicity conserving, helicity non-conserving and longitudinal amplitudes of the individual resonances will be of great value in assessing conflicting theoretical approaches. The extension of the measurement of exclusive resonance transition amplitudes from a maximum of ~ 4 GeV^2/c^2 to ~ 7 GeV^2/c^2, which we propose here, will enable us to access a crucial kinematic interval where there is currently no exclusive data.

The most significant feature of the inclusive electron scattering cross section in the resonance region, shown in Figure 2, is the existence of three broad maxima: the first, second and third resonance regions. In this interval there are about 20 known non-strange resonances. The first maximum is due to the $\Delta(1232)$ resonance. The most important states in the second resonance region, are the $S_{11}(1535)$ and the $D_{13}(1520)$. In the third resonance region, the strongest excitation at low Q^2 is the $F_{15}(1680)$ state, but the relative strength of the other six contributing states is not well determined, especially at increasing Q^2.

The current experimental situation for the resonances is that there exist no exclusive data of any kind for Q^2 above 3 GeV^2/c^2, and only a paucity of data at low Q^2. The existing single-arm inclusive electron scattering data have been evaluated (St-91), and equivalent transition form-factors as a function of Q^2 extracted for the three dominant peaks near W = 1232, 1535 and 1680 MeV. The result indicates that in the Q^2 region of the proposed experiments the cross sections may be approaching a $1/Q^4$ behavior, except

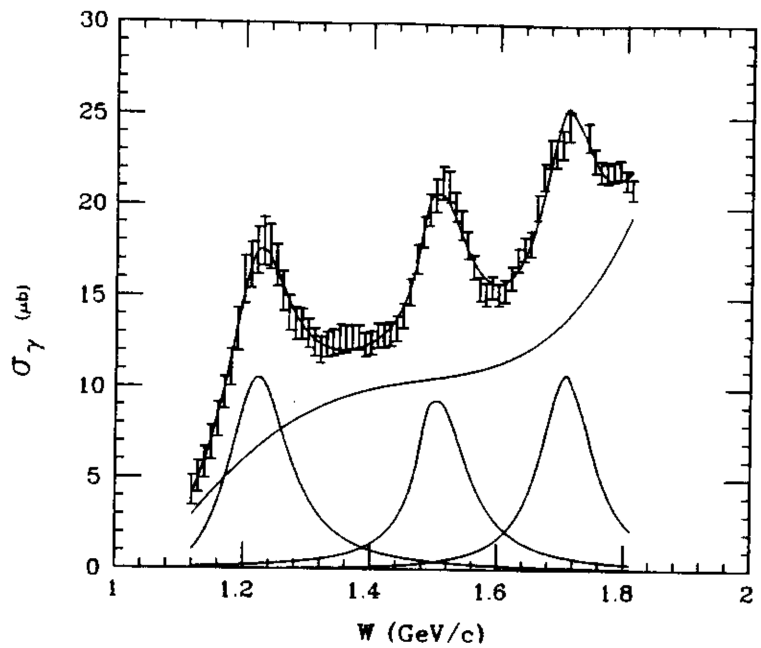


Figure 2. The virtual photon cross section for electron scattering at $Q^2 = 3$ GeV^2/c^2.

for the delta, whose cross section appears to be falling faster with Q^2. Since no inclusive data exist in this region it is difficult to say anything further, especially which of the resonant amplitudes are responsible for the observed Q^2 dependence of the inclusive cross section.

II Experimental Program

The large kinematic acceptance of the CLAS detector will allow us to make simultaneous measurements covering a large range of Q^2 and W with a large fraction of 4π acceptance for several decay channels. Running at an electron energy of 6 GeV will enable us to greatly extend the Q^2 range of high quality data considerably above the approved experiment. The maximum accessible Q^2 increases from about 4 GeV^2/c^2 to about 7 GeV^2/c^2 when the beam energy is increased from 4 to 6 GeV. By extending the measurements of the amplitudes of the most prominent resonances to 7 GeV^2/c^2 we will observe the kinematic regions where constituent quark models break down, and look for indications of the growing importance of hard perturbative phenomena.

Angular distribution measurements will be made for single meson decay channels such as $(e, e'\pi^o)$ and $(e, e'\eta)$. Isolating resonances and separating their multipoles will be greatly facilitated by the strong reduction in non-resonant contributions in neutral meson detection (see section III below). The neutral π^o and η channels will be measured by detecting the protons in the kinematically complete $p(e, e'p)\eta, \pi^o$ reactions. For the charged π^+ production, the π^+ will be directly detected. The following are examples of the kind of information we will access.

The Q^2 behavior of the delta resonance remains a controversial puzzle. The form factor decreases significantly as a function of Q^2 compared with that of the other states. At low Q^2 in a pure SU(6) constituent mean-field model the N$\rightarrow \Delta$ transition is purely M_{1+} involving a single-quark spin-flip. At high Q^2 the E_{1+}/M_{1+} ratio is expected to increase steadily with Q^2, and in the pQCD limit helicity conservation demands the equality $M_{1+} = E_{1+}$. A crucial test of our understanding of excited baryon structure, and the regions of validity of the extremely different models is to observe the evolution of the E_{1+} and M_{1+} multipoles. When E_{1+}/M_{1+} is as little as ~ 0.1 the decay angular distributions are very different than for a predominantly M_{1+} transition. Simulations show that we can expect to obtain definitive information on this crucial ratio over a large range of Q^2 (see Section III below).

The $S_{11}(1535)$ is one of the few large resonances which has a strong coupling to the η decay channel. At lower Q^2 the reaction $p(e,e'p)\eta$ is totally dominated by S-wave production and exhibits a clear resonant behavior with only small non-resonant contributions. For S-wave production the differential cross section contains only one transverse helicity amplitude A_{o+}, while at lower Q^2 the longitudinal coupling was found to be small. Therefore the resonant transverse amplitudes can be directly extracted from this data, with modest corrections due to non-resonant contributions. These experimentally attractive features will enable us to study this transition at a very early stage in the program.

The $P_{11}(1440)$, or Roper resonance, has been the the subject of considerable interest. In the non-relativistic quark model with harmonic oscillator potential this state is an $N = 2$ energy level with the same quantum numbers as the $N = 0$ nucleon. There has also been speculation that its P_{11} character makes it a candidate for the lightest hybrid baryon (Li-92), in which case one expects a very different Q^2 dependence from the one predicted in the quark model (Ca-94). A hybrid P_{11} will disappear at high Q^2whereas a $N = 2$ quark model state is predicted to become a prominent resonance. Since the Δ falls rapidly with Q^2, this may make the Roper, which is obscured at low Q^2, more accessible.

III Experimental Consideration

In preparation for this program members of the N* collaboration have undertaken major responsibility for construction of a large part of the CLAS spectrometer. Among the spokespersons on this proposal, V. Burkert is leading an effort at CEBAF to build the forward angle calorimeter, P. Stoler is in charge of construction of the gas Cerenkov system at Rensselaer, and M. Taiuti is in charge of building the large angle calorimenter in Italy. Concurrently we are developing the software to analyze the data, and to simulate experimental expectation. V. Burkert and Zh. Li have been been involved in this. The analysis software is being developed for the entire single pion portion of N* program (Bu-94).

We have been simulating the acceptances and resolutions for operation of the CLAS with a 6 GeV electron energy. The prognosis is quite favorable. For example, Figure 3 shows the missing mass resolution which is expected for the experiment $p(e,e'p)\pi^0$ at $Q^2 = 5$ GeV^2/c^2 near the peak of the delta resonance. The single pion peak appears very well separated from the two pion threshold.

The decomposition of the amplitudes for the individual resonances require angular distribution measurements of the exclusive meson decay channels. Using the simulation codes AO and SDA we have obtained acceptances for the reactions $p(e,e'p)\pi^0$ and $p(e,e'p)\eta$ corresponding to the proposed kinematics, and find they are very high (> 50 %) over nearly the full range of kinematic variables. This has enabled us to determine the expected statistical accuracy of the experiment . The following are some examples.

Figure 4 shows a simulated excitation curve for one month (30 days) running at a luminosity of 1×10^{34} cm^{-2}-sec^{-1} for the reaction $p(e,e'p)\pi^0$, at Q^2= 5 GeV^2/c^2, for an interval $\Delta Q^2 = 1$ GeV^2/c^2, and hadron cm decay angle $\theta = 60°$, $\phi = 90°$ within the interval $\Delta\phi = 60°$ and $\Delta\cos\theta = 0.2$. Note that the expected non-resonant contribution is significantly smaller than for inclusive electron scattering.

Figure 5 shows the expected statistics for virtual photon differential cross sections

Figure 3. Simulated missing mass resolution which is expected for the experiment $p(e,e'p)\pi^0$ at $Q^2 = 5\ \mathrm{GeV}^2/c^2$ near the peak of the delta resonance.

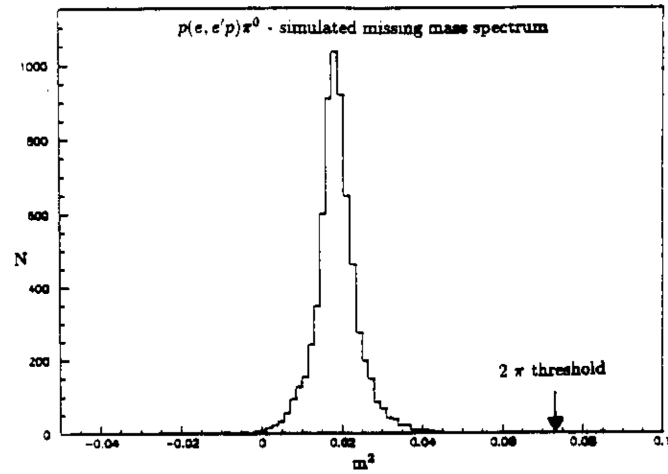
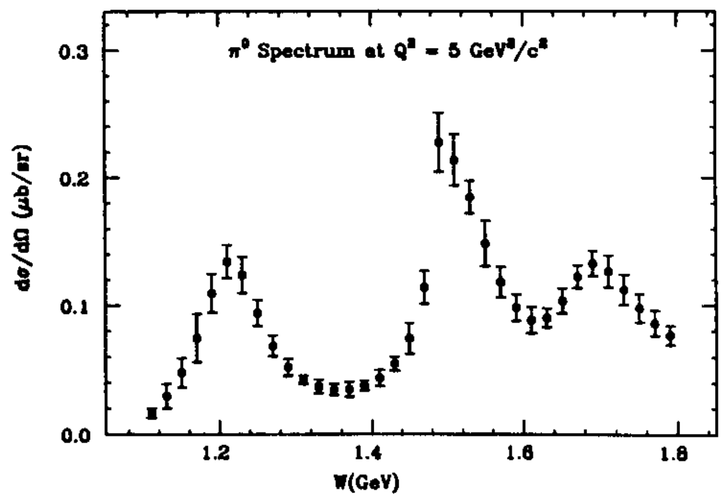


Figure 4. Simulation using the codes AO and SDA of the events for the reaction $p(e,e'p)\pi^0$ at $Q^2 = 5\ \mathrm{GeV}^2/c^2$ at hadron cm decay angle $\theta = 60°$, $\phi = 90°$ within the interval $\Delta\phi = 60°$ and $\Delta\cos\theta = 0.20$ for 30 days of beam time.



for the $\Delta(1232)$ $Q^2 = 5\ \mathrm{GeV}^2/c^2$ at $\phi = 30°$, $60°$, and $90°$, with $\Delta W = 100$ MeV, $\Delta Q^2 = 1\ \mathrm{GeV}^2/c^2$, and $\Delta\phi = 60°$ MeV. The curves are the expected angular distributions assuming $E_{1+}/M_{1+} = 0$, 0.1 and 0.2. The statistical accuracy of the data is quite high. For example a statistical fit for E_{1+}/M_{1+} over the entire angular range of simulated data at $Q^2 = 5\ \mathrm{GeV}^2/c^2$ gives $\delta(E_{1+}/M_{1+}) \sim 4 \times 10^{-3}$. However, we expect the uncertainty in E_{1+}/M_{1+} to be strongly affected by experimental systematic uncertainties and theoretical uncertainties in the underlying non-resonant contributions. To minimize the experimental uncertainties the collaboration plans a very extensive experimental program to calibrate the CLAS acceptance. We also expect major input from our theoretical collaborators to minimize uncertainties in the non-resonant contributions.

Figure 6. shows existing data on the ratio E_{1+}/M_{1+} for the $\Delta(1232)$, as well as the range over which we expect to obtain data. Since helicity conservation and pQCD require the ratio to approach 1, whereas the CQM predicted value is near 0, we will be in a very strong position to make definitive statements about the transition in the Q^2 region which we will access.

Figure 7 shows examples of simulated angular distributions for π° and η production at W near the $D_{13}(1520)$ and $S_{11}(1535)$ at $Q^2 = 3\ \mathrm{GeV}^2/c^2$ and $5\ \mathrm{GeV}^2/c^2$. Also shown are the existing data at $Q^2 = 3\ \mathrm{GeV}^2/c^2$. There are no experimental data above $3\ \mathrm{GeV}^2/c^2$,

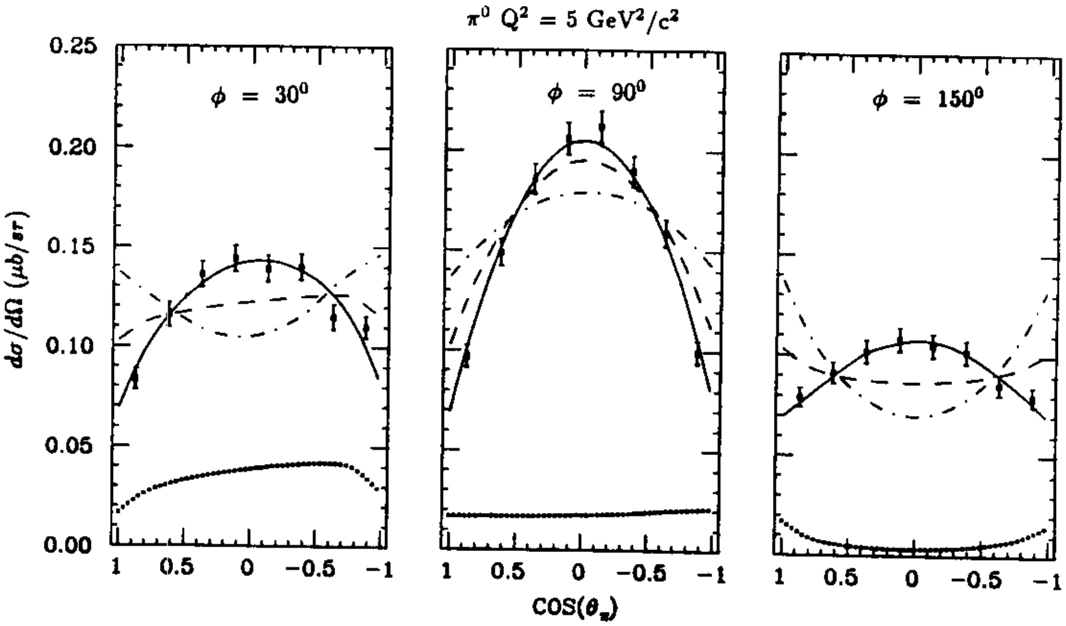
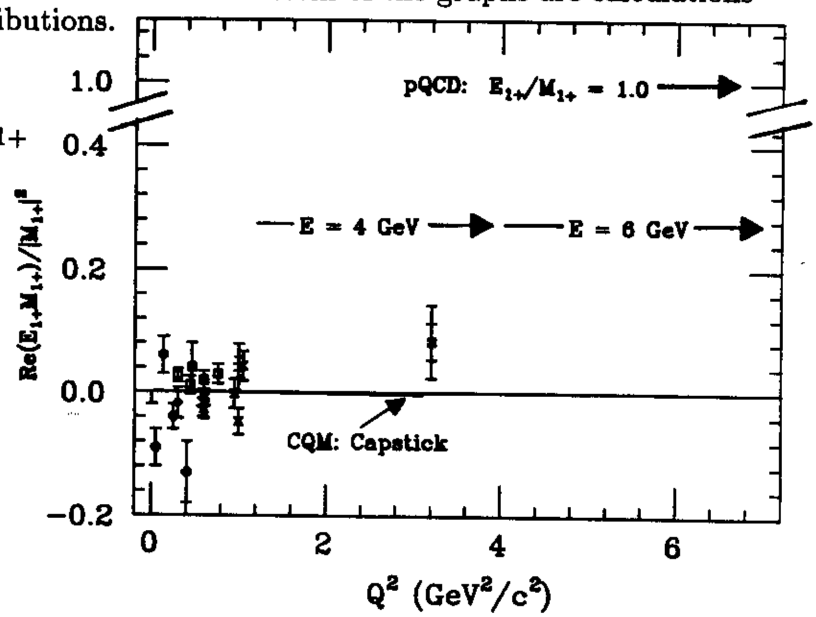


Figure 5. Simulated virtual photon differential cross sections at $Q^2 = 5$ GeV^2/c^2 of π° production for W at the $\Delta(1232)$ for $\phi = 30^\circ$, 60°, and 90°. The acceptances are $\Delta W = 100$ MeV, $\Delta Q^2 = 1$ GeV^2/c^2, and $\Delta\phi = 60^\circ$. The assumed luminosity is 1×10^{34} cm^{-2}-sec^{-1}, and the running time is 30 days. The curves are the expected angular distributions assuming $E_{1+}/M_{1+} = 0$ (solid), 0.1 (dashed) and 0.2 (dot-dash). The chained curves near the bottom of the graphs are calculations of non-resonant Born contributions.

Figure 6. The ratio E_{1+}/M_{1+} for the $\Delta(1232)$ and the statistics on E_{1+}/M_{1+}. The existing data is compiled by Bu-92. The pQCD prediction is 1, while a relativistic CQM prediction (Ca-92) is near 0. The horizontal arrows indicate the range of Q^2 accessed with electron beam energies of 4 and 6 GeV respectively.



and even at $Q^2 = 3$ GeV^2/c^2 the data are too poor to separate the two states adequately. The three curves appearing on the π^0 data correspond to different assumptions about the relative amplitudes of the two states. Remarkably, the strong interference between the two amplitudes provides a very high degree of sensitivity to the admixture of the D_{13} to the S_{11}. The η data in the figure assumes a pure S_{11} state without non-resonant contribution. The very large acceptance of the CLAS spectrometer will provide complete angular distributions similar to those shown over 8 to 10 ϕ bins covering 360°

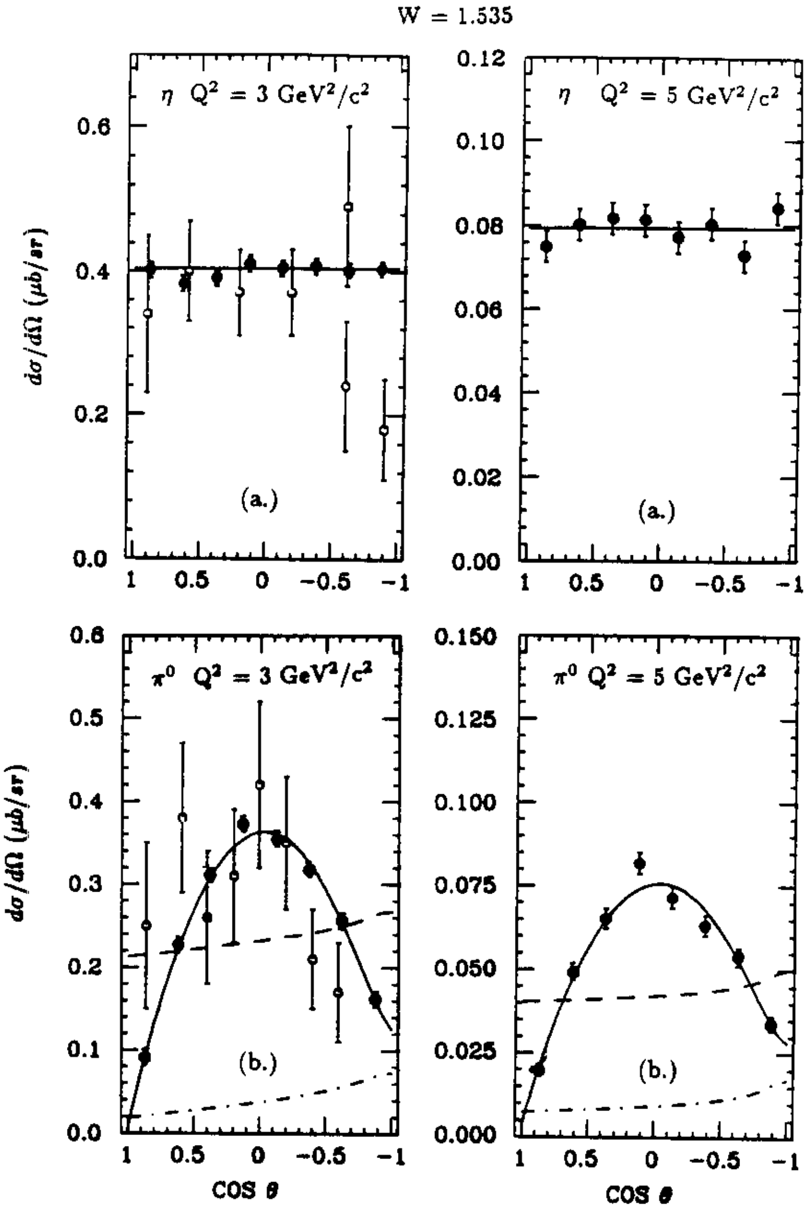


Figure 7. Simulated angular distributions for a.) η and b.) π^0 production at W = 1.535 GeV, near the $D_{13}(1520)$ and $S_{11}(1535)$ at $Q^2 = 3$ GeV^2/c^2 and 5 GeV^2/c^2. At $Q^2 = 3$ GeV^2/c^2 the acceptance is $\Delta W = 30$ MeV, $\Delta Q^2 = .5$ GeV^2/c^2, and $\Delta\phi = 30°$. At $Q^2 = 5$ GeV^2/c^{2}the acceptance is $\Delta W = 100$ MeV, $\Delta Q^2 = 1$ GeV^2/c^2, and $\Delta\phi = 45°$ MeV. The data points denoted by full circles are simulated, and those denoted by open circles, with large errors are the existing data for the same acceptances. There are no data at $Q^2 > 3$ GeV^2/c^2. For η production (upper figures), the solid curves are what one would expect for a pure S_{11} contribution with no non-resonant contribution. For π^0 production (lower graphs) the solid curves assume a ratio of D_{13} to S_{11} amplitudes of 20%, while the dashed curves assume a ratio of 0%. The dot-dash curves are calculated Born non-resonant contributions.

Conclusion. Extending the beam energy of experiment 89-003 to 6 GeV will enable us to measure resonance amplitudes in a new regime of Q^2, and test the limits of CQM's and the transition toward descriptions in terms of QCD. We request 30 days of beam with the standard CLAS full field settings

References:

(As-94) I. Aznauryan, Z.Phys.A346,297 (1993)
(Ar-86) R.G. Arnold et al., Phys. Rev. Lett. 57, (1986) 174.
(Ar-93) T.A. Armstrong et al., Phys. Rev. Lett., 70, (1993) 1212.
(Br-89) S.J. Brodsky, Lectures at the 27th International School of Subnuclear Physics, Ettore Majorana Center for Scientific Culture, Erice (1989),SLAC-PUB-5116, and references therein.
(Bu-92) V. Burkert;Int. J. Mod. Phys. E, Vol. 1, 421 (1992)
(Ca-92) S. Capstick, Phys. Rev. D46. 2864 (1994)
(Ca-94) S. Capstick and B.D. Keister, subm. to Phys. Rev. D (1994)
(Li-92) Zp. Li, V. Burkert, Zh. Li, Phys. Rev. D46, 70 (1992).
(St-91) P. Stoler, Phys. Rev. Lett. 66, (1991) .
P. Stoler, Phys. Rev. D44, 73 (1991) .
(St-93) P. Stoler, Physics Reports, 226, 103 (1993).